A COMPARISON OF FOREST STRUCTURE AT FOUR LOCATIONS IN COSTA RICA

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Abstract. (NDP) Tropical forests in different regions of Costa Rica experience varying levels of rainfall, temperature, wind stress, and light availability. We examined forest structure in seasonally dry deciduous forest, montane cloud forest and lowland rain forest. We predicted that the different climatic conditions which influence tree growth and canopy cover would result in different forest structures at each site. Moisture stress in the dry forest appeared to limit the size and number of trees and appeared to influence species composition. Water-storing trees such as species in the *Bombacaceae* were abundant. In the cloud forest, the high winds and abundant precipitation may contribute to the short, dense forest structure and successful epiphyte growth. The low elevation and warm temperatures characteristic of lowland rainforest may contribute to the growth of tall, moderately dense stands.

INTRODUCTION (CDW)

Different environmental factors such as rainfall, light availability, elevation, temperature, and seasonality affect tree growth and therefore forest structure. The Holdridge Life Zone Concept describes habitats based on some of these factors. We quantified and compared the physical structure of primary forests at four locations in Costa Rica, each representing a different Holdridge Life Zone (Table 1).

Study Sites

Palo Verde, located in the northwestern Guanacaste Province, experiences severe seasonality due to the rain shadow of the Cordillera Central. A six month dry season makes this the driest of our four locations. Most trees in the region are deciduous. We examined forest structure at two sites: one in a saddle between two peaks, and the other on the southern slope of one of the peaks.

Monteverde is a high elevation cloud forest experiencing intermediate rainfall and cold temperatures. The Monteverde forest is almost continually enveloped in clouds so moisture stress is minimal. Again we sampled two sites, one on the continental divide which is exposed to high winds, the other on the more protected Pacific slope.

Corcovado, a seasonally wet forest in southwest Costa Rica, is located near the Pacific ocean on the Osa Peninsula. This region experiences a three month dry season.

La Selva is a lowland rain forest on the Atlantic slope. There is no true dry season because prevailing winds drop rain as they are pushed up towards the Cordillera Central.

TABLE 1. Physical characteristics and classification of primary forest sites at four locations in Costa Rica (data from Hartshorn 1983).

Location *Site*	Holdridge Life Zone	Elevation (m)	Mean annual rainfall (m)	Seasonality
Palo Verde				
Saddle	Tropical Dry Forest	200	1-1.5	High
Slope	Tropical Dry Forest	100	1-1.5	High
Monteverde				
Continental Divide	Tropical Lower Montane Rain Forest	1800	2-3	Low
Slope	Tropical Lower Montane Wet Forest	1600	2-3	Low
Corcovado				
Lowland	Tropical Premontane Wet Forest	100	3-6	Moderate
La Selva				
Lowland	Tropical Wet Forest	70	3-4	Low

METHODS (AVB)

We sampled a total of six 500 m^2 plots which were chosen by the research group to be representative of the differences between the sites. Sites were not chosen randomly. We laid out a 50 m belt-transect and recorded data on all trees over 10 cm DBH (diameter at breast height) within 5 m of the tape. We recorded DBH, location along transect and canopy diameter of each tree. Heights of selected trees were measured using a clinometer. These measurements were used as a standard against which heights of other trees were estimated.

Epiphyte coverage was visually estimated and an average was taken for each site. Soil was collected at each site and weighed to obtain soil moisture content. Soil from Monteverde, Corcovado, and La Selva was dried in a drying oven until dry. Soil from Palo Verde was air dried. A canopy area index of each plot was calculated by dividing the total area of canopy coverage in each plot by the area of the plot. This index quantifies the number of canopies overlapping 1 m^2 of ground. These data, along with our preliminary on-site sketches, were used to generate drawings of the different canopy profiles at each site.

RESULTS (NEP)

We found great variation in forest structure between study sites (Fig. 1-6, Table 1). Tree density was lowest at Palo

TABLE 2. Comparison of forest structure in Palo Verde, Monteverde, Corcovado and La Selva, C. R. (Mean values ± SE; range)

Location	Density (#Trees/ $100m^2$)	Height m	DBH cm	Canopy Diameter (cm)	Canopy Area Index	Average % Ephiphyte	% Water Content in Soil
Palo Verde							
Saddle	16	12.0 ± 0.5 6.6-14.8	21.4 ± 4.3 12.7 - 86.7	7.3 ± 0.57 3.6-12.3	7.27	0	
Slope	18	13.3 ± 1.4 5.5 - 24	30.9 ± 4.7 10.8 - 84.3	8.6 ± 0.79 3.3 - 13.2	12.09	0	5%
Monteverde							
Continental Divide	39	9.4 ± 0.38 5.8 - 18	30.8 ± 6.2 11 - 192	5.0 ± 0.38 1.6 - 13	9.31	75	
Slope	24	15.5 ± 1.2 7.5 - 32.4	40.8 ± 6.0 13.5 - 137	7.1 ± 0.71 3.4 - 17.5	12.32	50	60%
Corcovado							
Lowland Anacard	37	21.1 ± 2.3 4 - 57	34.0 ± 7.1 10 - 212	8.0 ± 1.0 2.7 - 35	27.48	10	50%
La Selva							
Lowland Pentaclethra	26	19.0 ± 1.2 11 - 36.2	30.0 ± 4.5 10 - 88	6.9 ± 0.70 2.9 - 18.2	10.87	25	70%

Verde and greatest on the Monteverde continental divide and in Corcovado. Mean tree height was lowest in Palo Verde and greatest in Corcovado and La Selva. We found lowest mean DBH in Palo Verde and greatest mean DBH on the Monteverde slope. DBH's were comparable at the remaining four sites. Mean canopy diameter was smallest on the Monteverde continental divide and greatest on the Palo Verde slope. The canopy area index value was smallest in the Palo Verde saddle and was highest in Corcovado. We found no epiphytes in Palo Verde, whereas our estimation of epiphyte coverage on the Monteverde continental divide was 75%. Percent water content of soil at Palo Verde was 5% compared to 70% at La Selva (Table 2).

DISCUSSION (WLO)

Each of the primary forests sampled were influenced by local environmental conditions which are discussed below.

Palo Verde. In Palo Verde, trees were short and least dense, possibly due to moisture stress that results from the long dry season. Moisture content of soil was low relative to all sites. Epiphytes are incapable of growing in this moisture limited environment. Palo Verde's low canopy index and low variation in tree height was particularly obvious in the saddle (Fig. 1). Two nearby peaks limit light levels, which, coupled with intense competition from lianas may limit growth.

Surprisingly, trees on the slope had the largest canopy diameter despite the high moisture stress and poor soil. This may be due to the absence of lianas, the high light received by the south-facing slope, and the presence of certain tree species which are capable of storing water in their boles (i.e. *Bombacaceae).*

Monteverde. The high winds, low temperatures, and frequent misting events greatly affected the structure of the Monteverde cloud forest. A stunted forest of thin, small-canopy trees in a tightly packed stand characterized the continental divide. Precipitation carried by the easterly winds crossing the divide provided an ideal environment for the abundant epiphytes. On the south-facing slope of Monteverde, mean DBH was high. Trees were sheltered from the wind and received high rain and sunlight which provided favorable growth conditions.

Corcovado. Tall trees, spectacular buttresses, and large woody lianas grow in Corcovado. The short three month dry season, abundant rainfall, potentially rich, alluvial soil, and warm environment in low elevation apparently makes a suitable environment for tree growth. However, the relatively few epiphytes may be due to the short dry season. Tree density is similar to that at Monteverde, but there is greater variation in tree height. The emergent *Anacardium excelsum*, canopy, mid-canopy, and understory layers create an overlap of crowns, providing a high canopy area index.

La Selva. A moderately dense forest structure dominated by *Pentaclethra macroloba* resulted in a canopy of relatively uniform height (Fig. 6). Our plot did not include many common emergent trees such as *Dipteryx* spp., *Hieronyma* spp., and *Lecythis* spp. which were present in the forest. If we had sampled these trees, the height range would have been greater and the canopy area index larger. The soil in La Selva had the highest moisture content, possibly due to rainstorm two days prior to sampling.

Summary. Only one non-randomly selected plot was sampled in each area which limits the generality of our findings. We selectively chose areas that contained the most tree types which we felt represented the forest habitat. Therefore, the density of certain size classes in our samples may not be typical of the forest as a whole.

Future research might monitor randomly chosen, permanent plots over time to study the influence of abiotic factors on tree growth and densities. Overall, the trends in forest structure in the four Holdridge Life Zones sampled can best be explained by differences in environmental conditions.

LITERATURE CITED

Hartshorn, G. S. 1983. Introduction to plants. Pages 118-144 *in* D. H. Janzen, editor. Costa Rican Natural History. University of Chicago Press, Chicago, Illinois, USA.

FIG. 1. Profile of tropical dry forest in the saddle at Palo Verde.

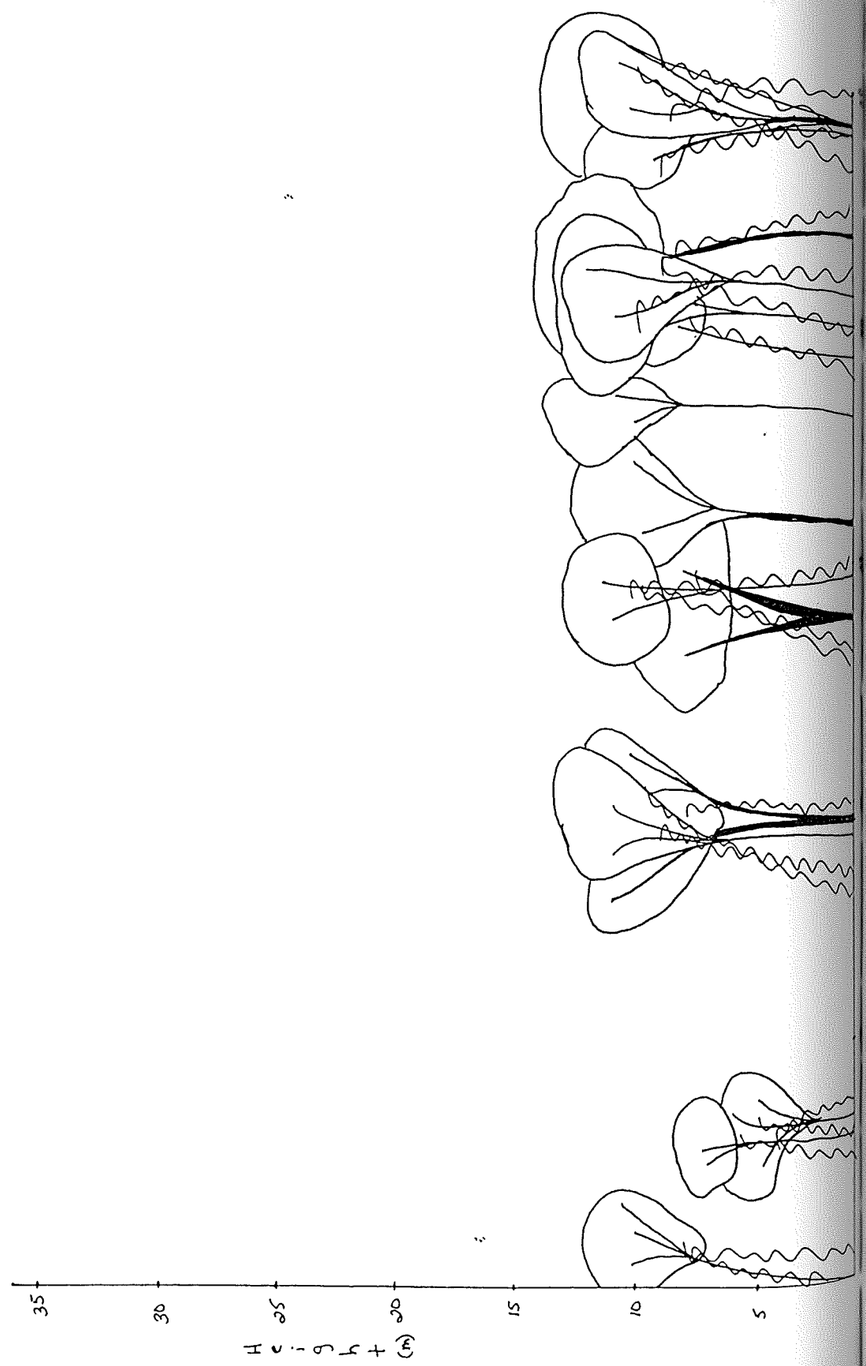

FIG. 2. Profile of tropical dry forest on the slope at Palo Verde.

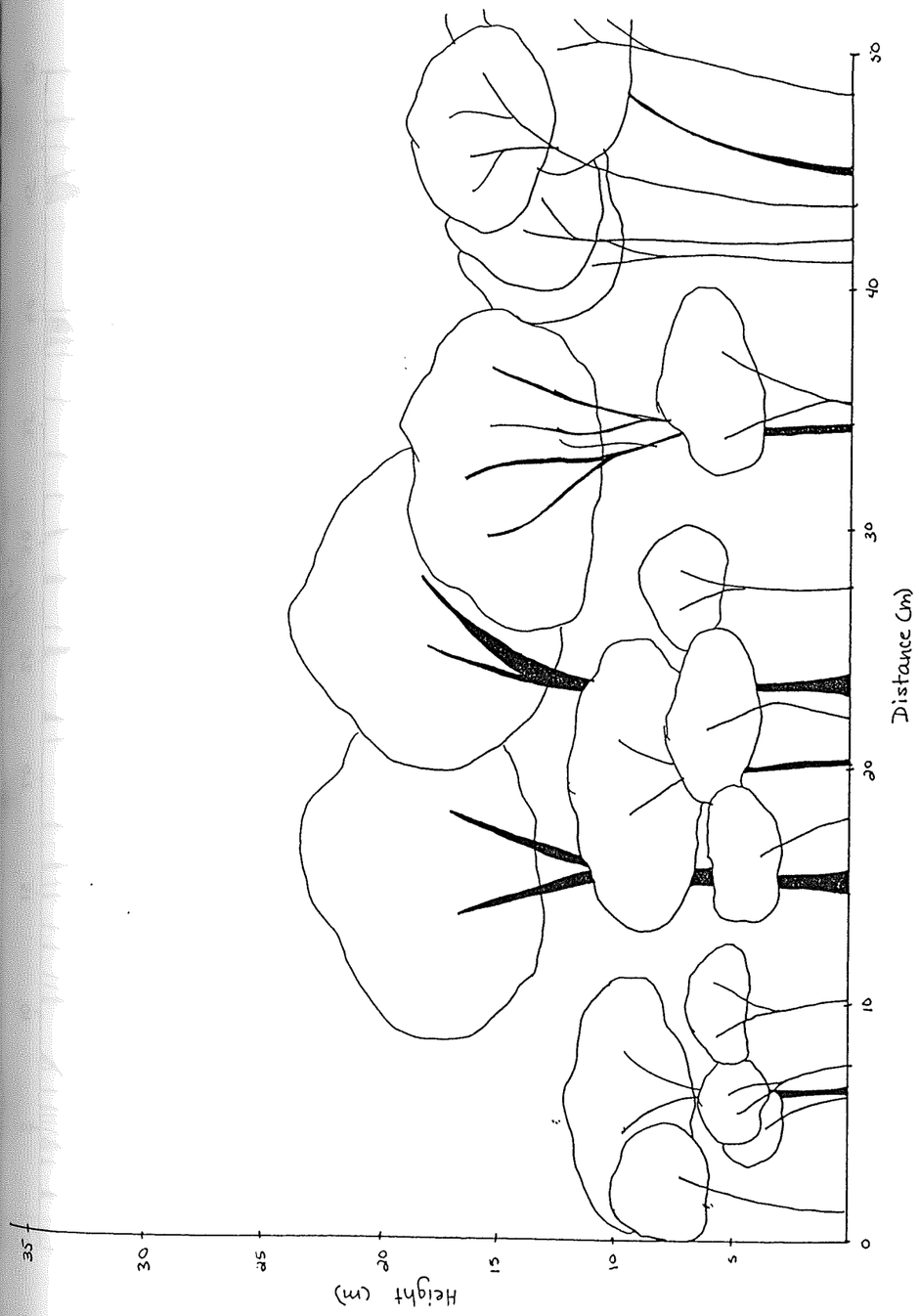

FIG. 3. Profile of montane cloud forest on the continental divide at Monteverde.

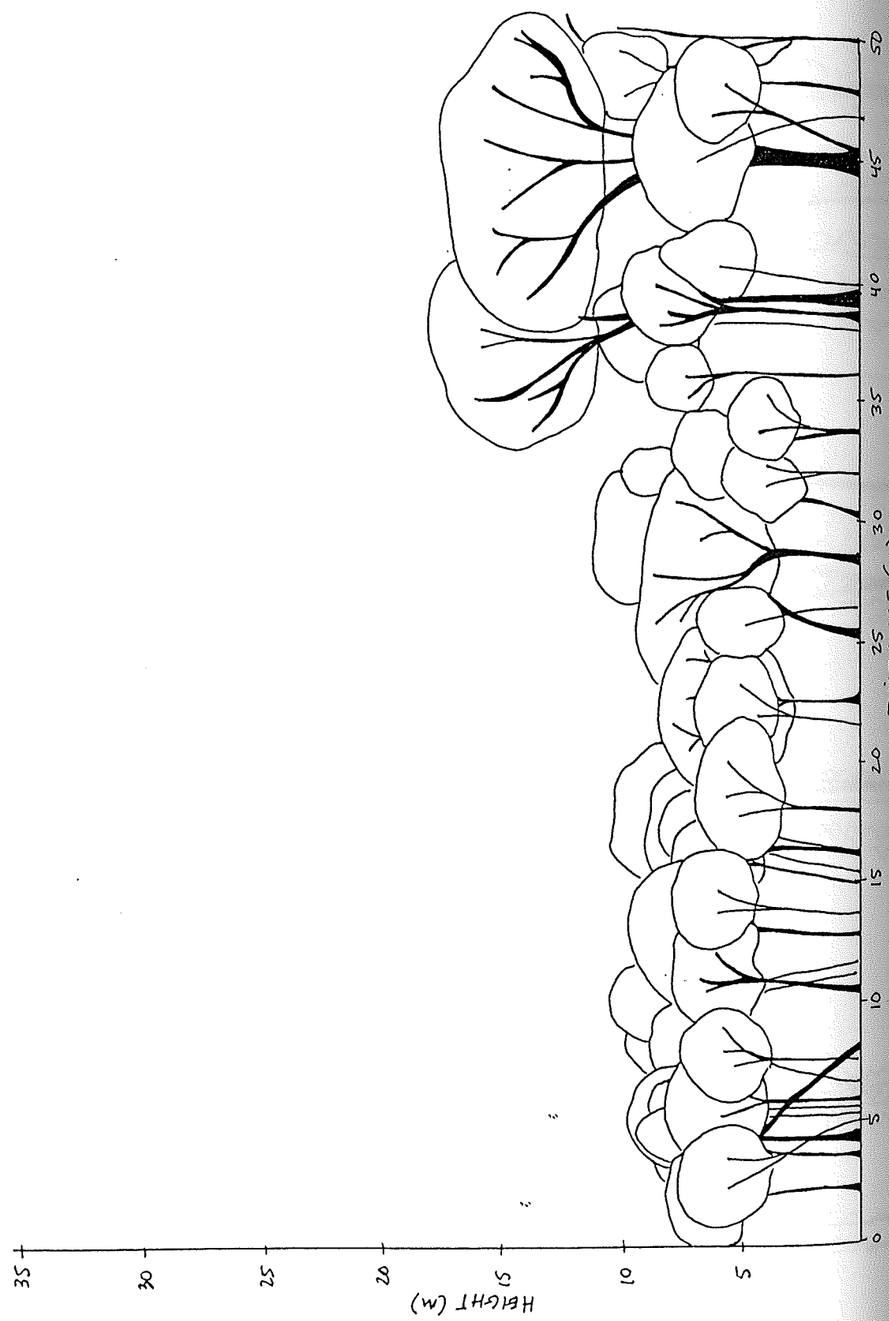

FIG. 4. Profile of montane forest on the slope at Monteverde.

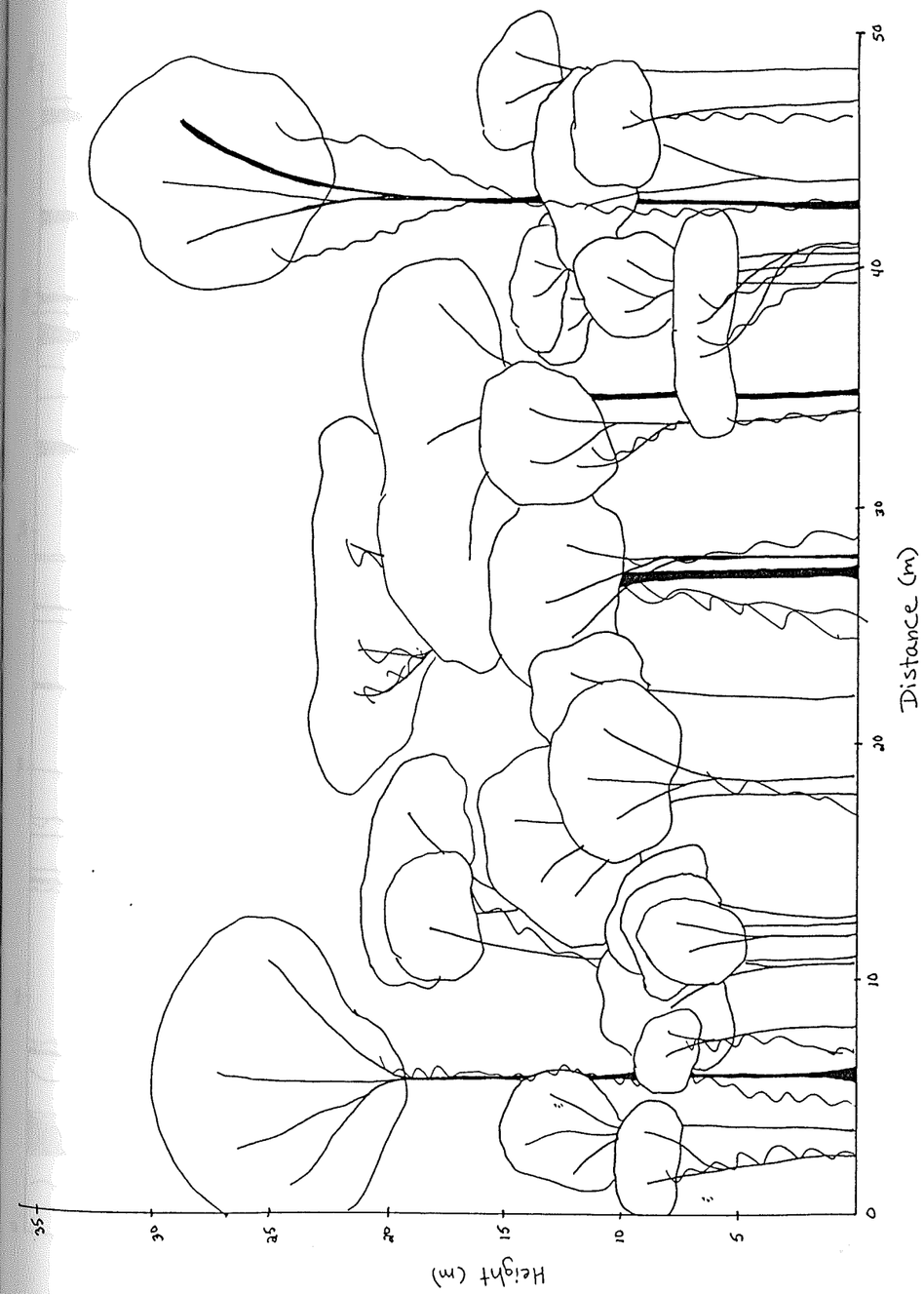

FIG. 5 Profile of lowland rainforest at La Selva
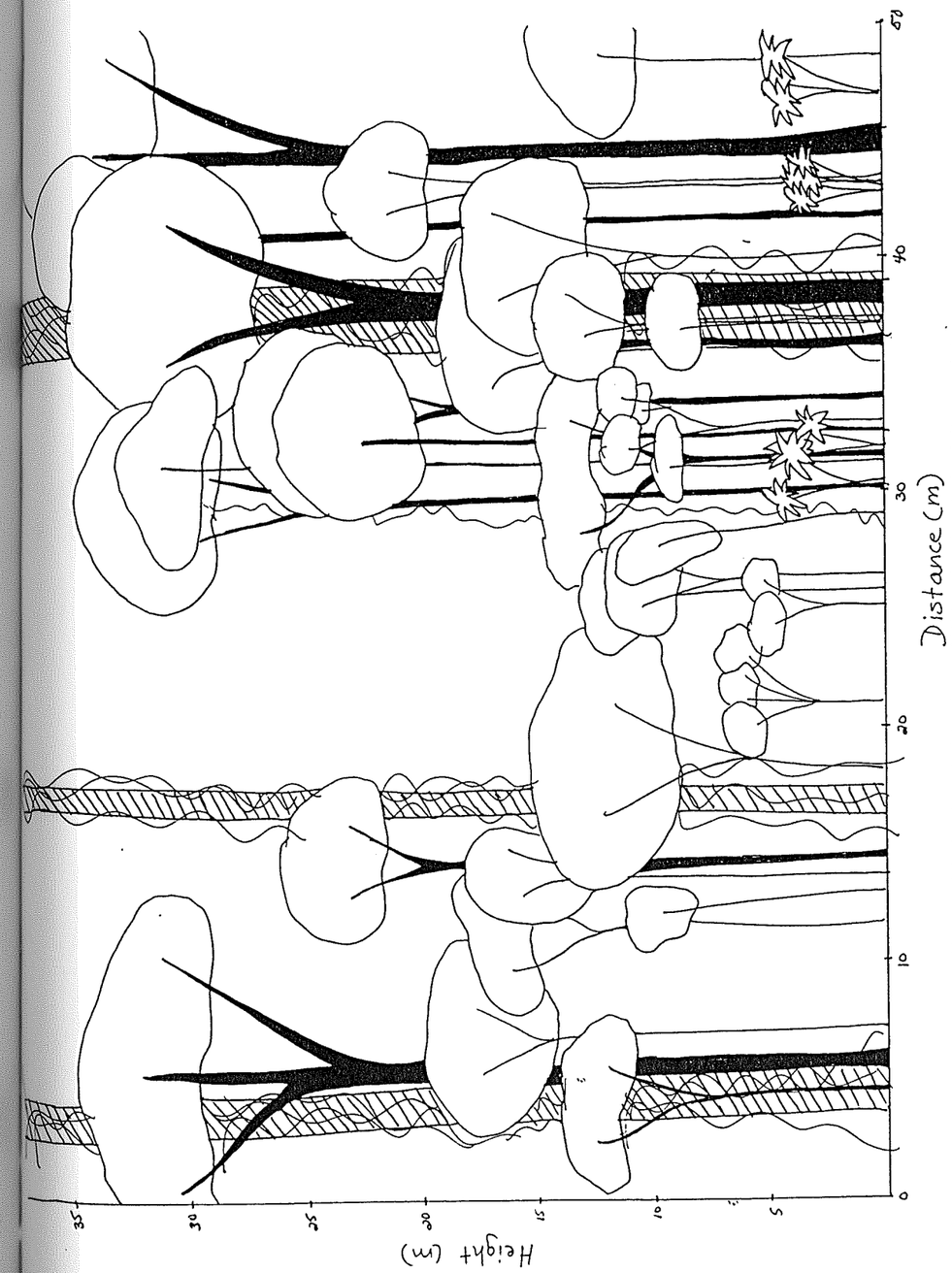
FIG. 6 Profile of seasonally wet rainforest at Corcovado